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# THE NOW FRONTIER

MAN LINKS EARTH AND PLANETS

## PIONEER TO JUPITER

N75-24637

PIONEER 11 ENCOUNTER  
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ISSUE NUMBER SEVEN  
PIONEER 11 ENCOUNTER

# PIONEER 11 ENCOUNTER

At 9:21 p.m. PST on Monday, December 2, 1974, Pioneer 11 will hurtle at the unprecedented speed of 107,373 miles per hour past Jupiter, only 26,600 miles above the Jovian cloud tops. This American spacecraft is man's second trip to the Solar System's largest planet, but it penetrates three times closer to Jupiter than did Pioneer 10 which flew by Jupiter 81,000 miles above the cloud tops almost one year beforehand.

The closer approach of Pioneer 11 is designed to probe deeper into the radiation belts of energetic electrons and protons that are trapped in Jupiter's magnetic field. Also the close approach permits the use of Jupiter's gravity and orbital motion to fling Pioneer 11 across the Solar System to meet with the next outermost planet, ringed Saturn, in 1979. Pioneer 11 is thus man's first attempt to use energy derived from a pass near Jupiter to fly to the next outer planet, an essential maneuver for continued economic exploration of the outer Solar System.

Not only is the trajectory of Pioneer 11 passing much closer to Jupiter than its predecessor, but also it is directed quite differently, so as to reduce the time that the spacecraft must be in the radiation belts. This is expected to safeguard the electronics and scientific instruments of Pioneer from damage from the energetic protons and electrons. Controllers have directed the spacecraft into the Jovian system from far below Jupiter's south

pole. Along this trajectory the spacecraft will hurtle almost straight up through the doughnut-shaped inner radiation belt, many thousands of miles per hour faster than any man-made object has traveled before.

Passage through the belt at high speed and high angle should allow Pioneer 11 to emerge unscathed while at the same time permitting the spacecraft to enter the narrow planetary flyby corridor that will ensure a later encounter with the planet Saturn.

Additionally, Pioneer 11's trajectory differs from its predecessor because the passage is counter to the direction of Jupiter's rotation (Figure 1). Thus, during the encounter, the spacecraft will sample a complete revolution of the planet's magnetic field and Jupiter's radiation belts, and will observe the planet's surface features over several planetary revolutions. Moreover, because the spacecraft approaches Jupiter from the south pole and leaves over the north pole, experimenters expect to obtain their first look at Jupiter's poles, impossible from Earth and from Pioneer 10. Instead of the familiar banded Jupiter, the polar views transmitted by Pioneer 11 should show a circular polar region bordered with concentric rings. One theory suggests that the polar atmosphere is transparent and will thereby permit Pioneer's instruments to look deep down into the Jovian atmosphere.

Since its launching on April 5, 1973, Pioneer 11 will have traveled 620 million miles when it reaches Jupiter. But it is destined for an even longer journey. After Jupiter passage it will travel high above the plane of the ecliptic—the plane of Earth's orbit around the Sun—and then descend to Saturn's orbit where it is scheduled to rendezvous with that planet. If Pioneer 11 does survive passage through Jupiter's radiation belts it will, in October 1979, provide mankind with a first close look at the unique ringed planet of the Solar System.

During the several weeks around the date of closest approach to Jupiter—termed periapsis—a team of spacecraft controllers, analysts and scientists at NASA's Ames Research Center (Figure 2), and personnel of NASA's Deep Space Network, will run a three-shift, 24-hours-a-day control operation. Applying experience obtained during the flyby of Pioneer 10 last year, they will be alert to danger to the distant spacecraft from possible but unpredictable problems arising in the environment of the Jovian system.

Most of the commands sent from the ground to the spacecraft during the encounter period, amounting to many thousands of instructions, will be directed to the imaging photopolarimeter which scans across Jupiter and some of its large satellites to gather information that will later be assembled by computer to form spin-scan images of these bodies (Figure 3). To send pictures of Jupiter and its satellites to Earth, the imaging photopolarimeter scans a light-sensitive device across the disc of the planet by the rotation of the spacecraft. The instrument measures brightness of the light that is gathered from each of many small areas of the scene. The brightness reading is converted into a binary number—somewhat like the dots and dashes of Morse code—and sent by radio from the spacecraft to Earth. Here the stream of impulses is converted back to appropriately positioned small gray areas on film, thus creating a facsimile of the view of Jupiter seen from the spacecraft. As the data needed to make one spin-scan image of the planet has to be gathered over a period of time, sometimes taking as long as one hour, and because the spacecraft is moving and Jupiter is rotating on its axis, the pictures reconstructed at Earth are distorted.

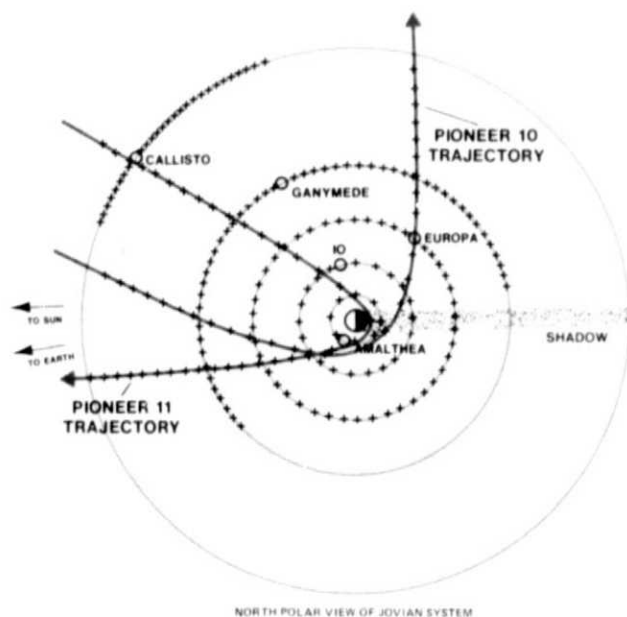


FIGURE 1. The Pioneer 10 and Pioneer 11 flybys of Jupiter. The positions of the Galilean satellites, Callisto, Ganymede, Europa and Io and of the innermost satellite Amalthea, are shown at the time of periapsis of Pioneer 11. The dots on the orbits show the movement of the satellites and both Pioneer spacecraft over intervals of two hours.

Later the distortions are removed by further computer processing of the returned data, but this enhancement of the returned images takes time.

Information from the spacecraft arrives back at Earth on three large antennas, 210-foot diameter dishes as large as football fields. One is in the Mojave Desert at Goldstone, California. Another is in Spain, and the third is in Australia. Thus as the Earth turns on its axis and the spacecraft sets at one of these stations, the spacecraft rises at the next station. Signals can accordingly be received uninterrupted for 24 hours each day.

## SCIENCE EXPERIMENTS

The science experiments to be made by Pioneer 11 in the Jovian system are much the same as those made by Pioneer 10 (Table 1).

- Measure Jupiter's magnetic field and magnetosphere with two instruments called magnetometers.
- Sense the interactions of Jupiter with the solar wind—the stream of charged particles flowing outward from the Sun across the Solar System—by use of an instrument that detects energetic electrons and protons.
- Measure the intensities, energies, and distribution of energetic electrons and protons in the radiation belts of Jupiter by use of four particle detecting experiments.
- Check on meteoroids and dust near Jupiter by means of a special four-telescope systems and a group of panels that detect punctures from impacting meteorites.
- Sense Jupiter's atmospheric composition and provide a thermal map of Jupiter's heat emission by use of instruments that measure ultraviolet and infrared radiation beyond the visible spectrum.
- Obtain spin-scan images of Jupiter and its clouds and of several of its large satellites, using the imaging photopolarimeter.
- Measure the atmospheric characteristics of the Jovian atmosphere by observing the changes to the radio waves from the spacecraft as it passes into and emerges from occultation by Jupiter.
- Improve measurements of the orbit of Jupiter and its satellites and the masses of these bodies by precise tracking of the motion of the spacecraft as it passes through the Jovian system.



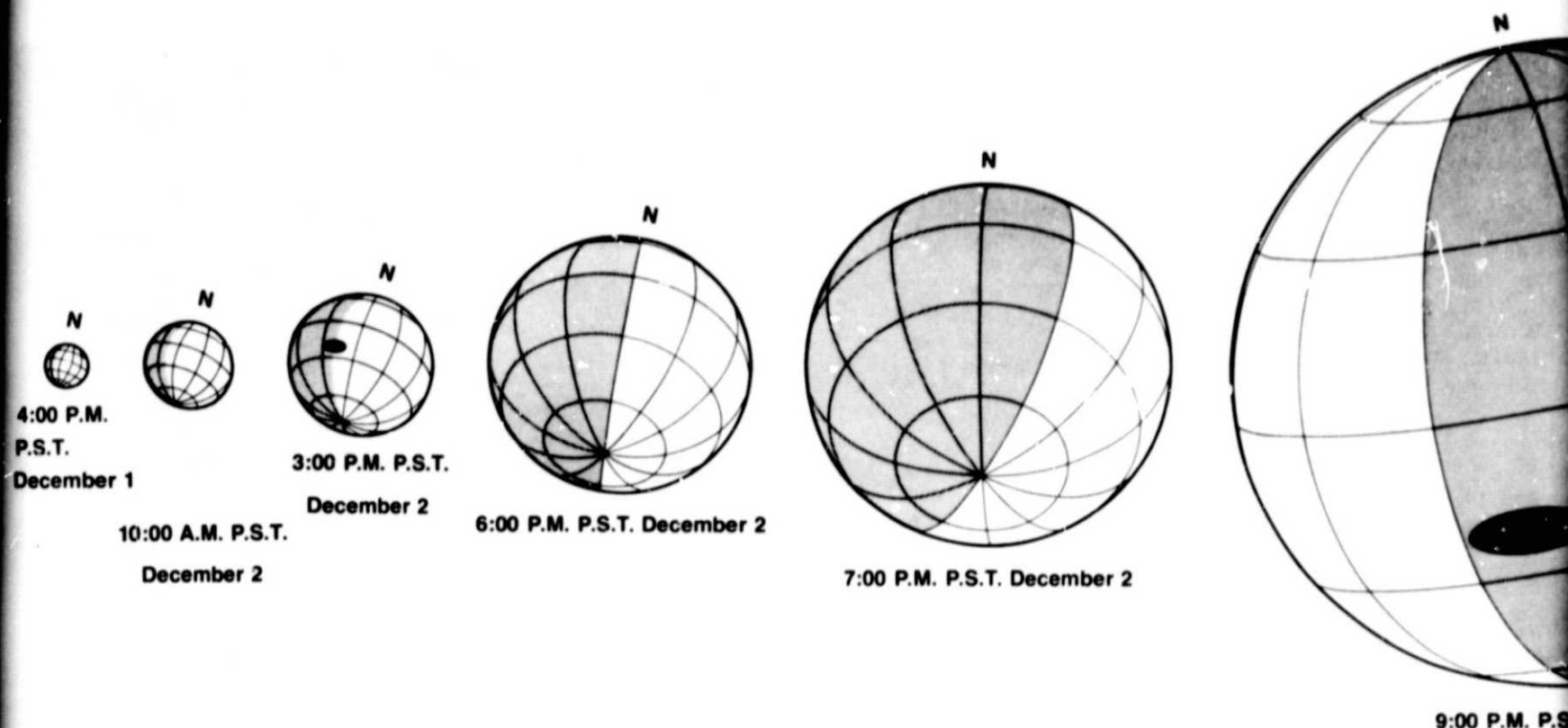
Figure 2. The distant spacecraft is controlled from NASA Ames Research Center near San Francisco, California, where teams of flight controllers, scientists, and engineers maintain 24-hours watch during the period of encounter. (Photo of personnel at consoles at the PMOC)



Figure 3. A typical spin-scan image of Jupiter returned from Pioneer 10 when it flew past Jupiter in December 1973. Pioneer 11 will return similar pictures but at different look angles. (Photo of Jupiter by Pioneer 10).

DATE	TIME	EVENT
NOV. 30	11:28 p.m.	ULTRAVIOLET MEASUREMENT OF CALLISTO
DEC. 1	11:26 a.m.	ULTRAVIOLET MEASUREMENT OF GANYMEDE
	10:18 p.m.	INFRARED MEASUREMENT OF CALLISTO
2	12:21 a.m.	CLOSEST APPROACH TO CALLISTO, 488,730 MILES
	1:50 a.m.	ULTRAVIOLET MEASUREMENT OF GANYMEDE
	1:56 p.m.	INFRARED MEASUREMENT OF GANYMEDE
	2:09 p.m.	CLOSEST APPROACH TO GANYMEDE, 430,195 MILES
	2:45 p.m.	ULTRAVIOLET MEASUREMENT OF EUROPA
	5:00 p.m.	START INFRARED MEASUREMENTS OF JUPITER
	5:13 p.m.	INFRARED MEASUREMENT OF AMALTHEA
	7:02 p.m.	INFRARED MEASUREMENT OF IO
	7:09 p.m.	CLOSEST APPROACH TO IO, 195,120 MILES
	8:15 p.m.	CLOSEST APPROACH TO EUROPA, 364,575 MILES
	10:30 p.m.	CLOSEST APPROACH TO AMALTHEA, 79,229 MILES
	10:52 p.m.	INFRARED MEASUREMENTS OF AMALTHEA
	11:00 p.m.	INFRARED MEASUREMENTS OF JUPITER
3	7:58 a.m.	INFRARED MEASUREMENT OF IO
	11:43 p.m.	INFRARED MEASUREMENT OF GANYMEDE
4	9:45 p.m.	INFRARED MEASUREMENT OF CALLISTO

TABLE 1. Some Experiments



FOLDOUT FRAM

Figure 4. This series of drawings produced originally on a computer appear from the Pioneer 11 spacecraft during the encounter period. details of the planet's north and south polar regions.

## THE ENCOUNTER SEQUENCE

Unlike Pioneer 10, Pioneer 11 goes by Jupiter against the direction of the planet's rotation. After passing in front of Jupiter as the planet moves along its orbit round the Sun, the spacecraft then goes around the dark side of Jupiter and completes a circuit of the planet by crossing the spacecraft's own incoming trajectory and heading for Saturn.

Views of Jupiter as seen from the spacecraft are shown in (Figure 4). These drawings resemble the PICS television images which will be displayed quickly as information comes to Earth and will be made available to commercial television networks. Before closest approach of the spacecraft to Jupiter the terminator—boundary between day and night on the planet—is near the left hand edge of the disc. After closest approach, the terminator will be near the upper right-hand edge of the disc of the planet. Most of the time the planet will appear gibbous, i.e. shaped half-way between a half moon and a full moon. A crescent-shaped Jupiter will be seen only very near to periaapsis.

On this encounter there is no opportunity for the spacecraft to occult any of the Jovian satellites, so

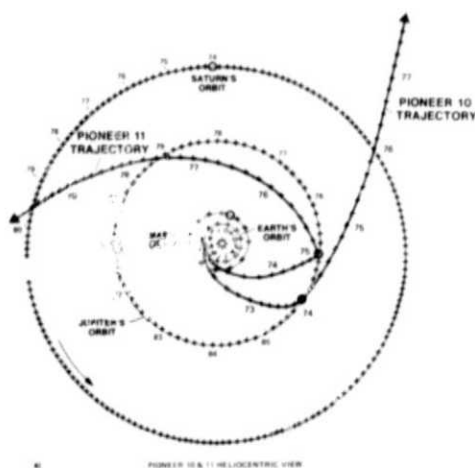
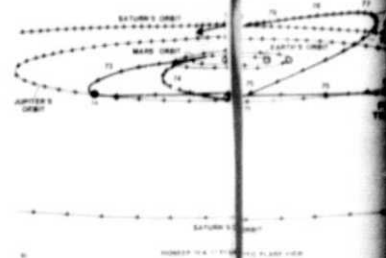


Figure 5. a) is a diagram of the paths of Pioneer 10 and Pioneer 11 from Earth to Jupiter and beyond. Pioneer 10 shoots beyond Jupiter right out of the Solar System. Pioneer 11 zooms around Jupiter which flings it right across the Solar System to intercept Saturn on the opposite side of the Sun in 1979. The dots on the orbits are positions at one month intervals.

their atmospheres cannot be probed directly as was the atmosphere of Io when Pioneer 10 went behind that satellite.

The flyby trajectory is inclined at an angle of about 50 degrees to Jupiter's equator. As a result, the Pioneer 11 post flyby trajectory appears to proceed straight up out of the ecliptic relative to Jupiter. Actually the spacecraft almost paces Jupiter around the planet's solar orbit, but rises high above Jupiter until, in 1977, it begins to fall back toward the ecliptic plane for its rendezvous with Saturn (Figures 5a and 5b).

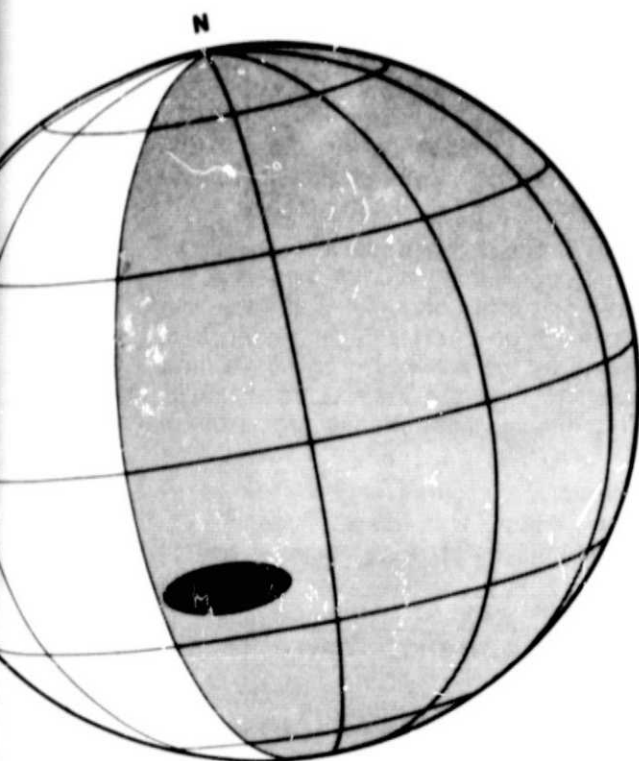


b) These same trajectories are shown here in almost end-on view. Pioneer 11 rises high above Jupiter before descending on the opposite side of the orbit.

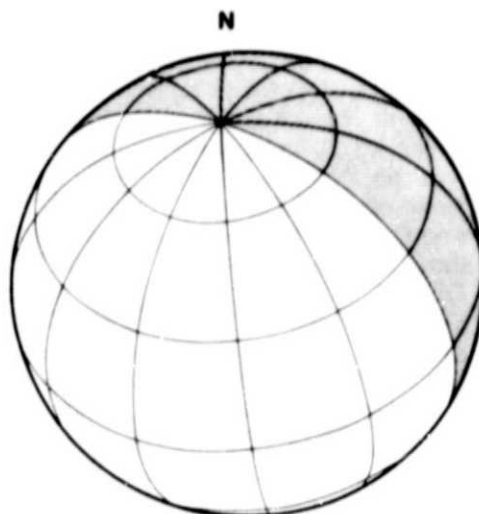
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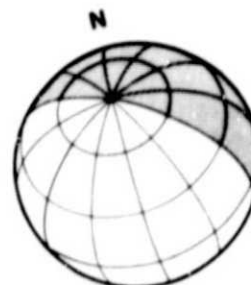




9:00 P.M. P.S.T. December 2



10:00 P.M. P.S.T. December 2



Midnight P.S.T. December 2



4:00 A.M. P.S.T.  
December 3

ed originally on a computer shows how the planet Jupiter will during the encounter period. This new view of Jupiter will reveal polar regions.

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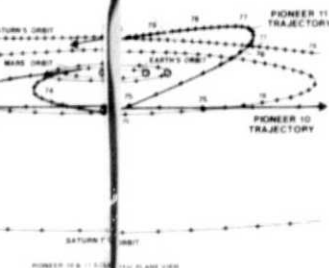
As with Pioneer 10 there are five stages of the encounter (Table 2). The first occupies about three weeks after November 2, when the spacecraft passes from interplanetary space into the outer regions of the Jovian system, moving from about 15 million to 6 million miles from the planet.

Stage Two covers entry into the inner system. Sometime after 8:00 a.m. on November 25 Pioneer 11 is expected to pass through the bow shock wave in the solar wind created by Jupiter's magnetic field. A short while later, the spacecraft

will enter the magnetosphere where the magnetic field of Jupiter prevents the solar wind from approaching closer to the planet's surface.

Stage Three is that period when Pioneer 11 continues flying through the outer magnetosphere from about 3 to 2 million miles from the planet.

**OLDOUT FRAME 2**



DATE	TIME P.S.T	DISTANCE FROM JUPITER, kilometers	STAGE OF ENCOUNTER
NOV. 2	4:00 p.m.	27,398,000	1
12	4:00 p.m.	19,162,000	
22	4:00 p.m.	10,646,000	
27	4:00 p.m.	6,111,000	2
30	4:00 p.m.	3,103,000	
DEC. 1	4:00 p.m.	1,956,000	3
2	9:21 p.m.	114,000*	4
3	4:00 p.m.	1,382,000	5
4	4:00 p.m.	2,617,000	
8	4:00 p.m.	6,631,000	
13	4:00 p.m.	11,127,000	
23	4:00 p.m.	19,615,000	
31	4:00 p.m.	26,207,000	

\*Note: Distances are from center of Jupiter. Closest approach is to 42,826 kilometers above the cloud tops.

in almost end-on view to illustrate how the path of Pioneer 11  
ing on the opposite side of the Sun to meet with Saturn on its

TABLE 2. Distances During Encounter

Stage Four is the period around closest approach, covering the day and a half before and after periapsis. Here is where the spacecraft makes most of its measurements and flies by the large inner satellites. Pioneer 11 makes hundreds of spin-scan images of the planet and several images of the large satellites and flies through the inner radiation belt.

During Stage Five, Pioneer 11 leaves Jupiter behind and repeats many of the earlier experimental sequences but in reverse order.

On November 7, during Stage One of the encounter, Pioneer 11 crosses the orbit of Hades, outermost satellite of Jupiter. In the next few days the spacecraft successively crosses the orbits of Pan and Andraستا. By November 21 Pioneer 11 crosses the orbit of Hera at just over 7 million miles from Jupiter; then the orbits of Demeter and Hestia. But the Jovian system is so big that despite the enormous speed of Pioneer it is not until December 1, the day before closest approach that the spacecraft begins to cross the orbits of the large inner satellites. Pioneer 11 comes within 488,730 miles of Callisto, which is as large as the planet Mercury. Next the spacecraft makes its closest approach to Ganymede (larger than Mercury) of 430,195 miles, then passes within 195,120 miles of Io, which is larger than Earth's Moon. Finally Pioneer 11 passes at 364,575 miles of Europa which is as large as the Moon. And unlike Pioneer 10, Pioneer 11 crosses the orbit of Amalthea, the innermost of Jupiter's satellites and approaches to within 79,224 miles of that tiny world (Table 3).

The spacecraft will first detect the presence of Jupiter as it crosses the bow shock, perhaps as early as 8:00 a.m. on

November 25. About 9:00 p.m. on November 26 the spacecraft should enter the magnetosphere. Imaging (picture taking) and photometry (light analysis) of Jupiter starts on November 2 over a period of 4 to 8 hours each day through November 24, and then continues for 23 hours each day until 3:00 p.m. on December 9. By 9:21 p.m. on November 30 all pictures of Jupiter should become better in quality than those obtained by telescope from Earth. During the close encounter period Pioneer 11 should also return 3 pictures of Callisto and one each of Ganymede and Io. This will be the second time that Ganymede has been photographed but the first time for Callisto and Io.

Pioneer 11 also inspects Callisto, Ganymede, and Europa in ultra-violet light and makes infrared measurements of Callisto, Ganymede, Amalthea and Io (Table 4). Some measurements are repeated on the outbound passage.

Just before closest approach at 9:21 p.m. on December 2, Pioneer 11 enters the cold blackness of Jupiter's shadow, and 40 seconds afterwards is hidden from Earth by the bulk of the planet. A radio blackout occurs as the spacecraft hurtles through the most intense region of the radiation belts.

Mission controllers and scientists will not know if Pioneer 11 has survived the radiation until 9:43 p.m. (21 minutes and 44

DATE	TIME	EVENT
NOV. 25	8:00 a.m.	ENTER JUPITER'S BOW SHOCK WAVE (EARLIEST)
26	8:00 a.m.	ENTER JUPITER'S MAGNETOSPHERE (EARLIEST)
DEC. 2	3:21 p.m.	ENTER RADIATION BELT AT 3.5 JUPITER DIAMETERS FROM CLOUDS AND 6 HOURS FROM CLOSEST APPROACH.
	9:00 p.m. + 21 SECONDS	GO INTO SHADOW OF JUPITER FOR 33 MINUTES AND 31 SECONDS OF SOLAR OCCULTATION
	9:00 p.m. + 42 SECONDS	GO BEHIND JUPITER FOR 42 MINUTES AND 2 SECONDS OF RADIO OCCULTATION (BLACKOUT).
	9:21 p.m.	CLOSEST APPROACH (PERIAPSIS)
	9:43 p.m.	OUT OF OCCULTATION, RADIO SILENCE SHOULD END.
3	3:21 a.m.	LEAVE RADIATION BELT
9	8:00 p.m.	LEAVE MAGNETOSPHERE (LATEST)
10	MIDNIGHT	LEAVE BOW SHOCK (LATEST)

TABLE 4. Some Important Events

seconds after periapsis), when the spacecraft emerges from behind Jupiter and radio contact can again take place. If Pioneer 11 does survive, information will again pour back over the radio link to Earth, and Pioneer will continue its spin-scan picture taking and other scientific observations as it speeds from the Jovian system.

## JUPITER PICTURES

Picture taking sequences of Pioneer 11 are summarized in Table 5. Color pictures will start to be interesting around November 2 when the planet, a little over 17 million miles from the spacecraft, will fill 1/50th of the imaging photopolarimeter's 14 degree field of view. By November 27 Jupiter will occupy 1/10th of the view, and by November 29, 1/7th.

SATELLITE	DATE	TIME PST	DISTANCE FROM JUPITER	
			miles	km
HADES	NOV. 7	4:30 a.m.	14,683,000	(23,632,000)
POSEIDON	7	4:49 p.m.	14,417,000	(23,204,000)
PAN	8	7:50 p.m.	13,841,000	(22,276,000)
ANDRASTA	10	7:29 p.m.	12,820,000	(20,634,000)
HERA	21	10:03 a.m.	7,248,000	(11,667,000)
DEMETER	21	10:50 a.m.	7,231,000	(11,639,000)
HESTIA	21	5:21 p.m.	7,084,000	(11,403,000)
CALLISTO	DEC. 1	5:27 p.m.	1,125,295	(1,812,800)
GANYMEDE	2	8:01 a.m.	624,953	(1,001,140)
EUROPA	2	2:06 p.m.	372,803	(601,780)
IO	2	5:23 p.m.	217,945	(352,560)
AMALTHEA	2	8:10 p.m.	68,630	(137,260)

TABLE 3. Times of Crossing Satellite Orbits

The planet's disc will exceed the field of view of the imaging instrument at 12 hours before periapsis so that only part of Jupiter will subsequently be imaged until the spacecraft moves away from the planet again.

Since most of the Pioneer 11 pictures will be views down toward either the north or south pole, the general appearance of Jupiter will be dramatically different from the Pioneer 10 or Earth view—the new pictures will show concentric circular zones around each pole instead of the familiar parallel bands seen in telescopes from Earth.

Details shown in every picture in the 96-hour period centered on periapsis should be better than the best views from Earth-based telescopes. Pioneer will be taking its best pictures in the 24 hours before and after periapsis when within about one million miles of Jupiter. Several close-up pictures of Jupiter's cloud tops taken near periapsis will be somewhat distorted at first viewing but they will be improved by subsequent computer processing. The picture just before periapsis, which will show a part of the surface of the planet including the Great Red Spot, will be about five times better

in detail than the best pictures from Earth. However, during closest approach the intense particle radiation in the belt may cause the photopolarimeter to cease to operate temporarily, or may reduce the quality of the images.

During the 96 hours centered on periapsis the spin-scan imaging system will send to Earth about 40 pictures of the full planet, many pictures of portions of the surface, three of the satellite Callisto, and one each of Ganymede and Io. As Pioneer 11 swings around Jupiter, Sun angles not possible from Earth (and not obtained from Pioneer 10) will be seen with almost every picture.

Incoming color and black and white pictures will be displayed on TV monitors as they arrive from Pioneer. They will then be photographed from the monitors and distributed to the news media.

## ON TO SATURN

When Pioneer 11 heads out from the Jovian system its mission is by no means complete. It will become the first spacecraft from Earth to fly by the mighty planet Saturn, only slightly smaller than Jupiter but with a unique ring system. (Figure 6).

In 1979 the spin-scan imaging system will provide mankind with the first close-up views of satellites of Saturn, the several distinct rings, and the cloud bands of the planet itself. And the scientific experiments with Pioneer 11 will sense the effects of Saturn on the solar wind, measure the heat radiated from the planet, and search for a magnetic field. After its encounter with Saturn Pioneer 11 will head out into interstellar space, mankind's second emissary to the stars.

## STUDY PROJECTS

### ONE

Take the various events listed in Tables 1 through 5 and make a combined listing of the sequential happenings when Pioneer 11 flies through the Jovian system. List the date, time, what happens; and leave a column for remarks about each happening. Give distances in both kilometers and miles. It will be necessary for you to use simple multiplication, a slide rule, or a desk calculator to make the conversions between the English and the Metric systems.

### TWO

Use the list you have made: during the encounter watch TV, listen to radio, and read newspapers to check each event as it is reported. Fill in remarks as to what is discovered.

### THREE

As a classroom project place a geometrical drawing on the blackboard, a large square or a triangle. Each student makes a 1/4 inch hole in the center of a card. Holding the card at arms' length in front of the eye it is impossible to see all the geometrical design on the board, only part of it. However, by scanning the hole across the blackboard in a series of sweeps, the student can see the whole of the figure on the blackboard; but not all at one time. This illustrates the spin-scan technique used to build up a picture of Jupiter over a period of time by scanning the disc with a small aperture telescope.

## READING LIST

Watch TV newscasts and special programs  
Listen to radio newscasts  
Read your local newspaper or national newsmagazine during the encounter period.

DATE	APPROXIMATE NUMBER OF PICTURES	OBJECT
NOV. 25	11	JUPITER
26	25	JUPITER
27	17	JUPITER
28	22	JUPITER
29	15	JUPITER
30	24	JUPITER
DEC. 1	14	JUPITER
	2	CALLISTO
2	8	JUPITER
	1	CALLISTO
	1	GANYMEDE
3	11	JUPITER
	1	IO
4	15	JUPITER
5	18	JUPITER
6	10	JUPITER
7	22	JUPITER
8	28	JUPITER
9	19	JUPITER
TEST IMAGES OF JUPITER WILL BE OBTAINED BEFORE AND AFTER THE PERIOD DETAILED ABOVE. ENCOUNTER ENDS AT 4:00 P.M. 3 JANUARY 1975.		

TABLE 5. Images of Jovian Objects